Production of Direct Photons and Jets at the Tevatron

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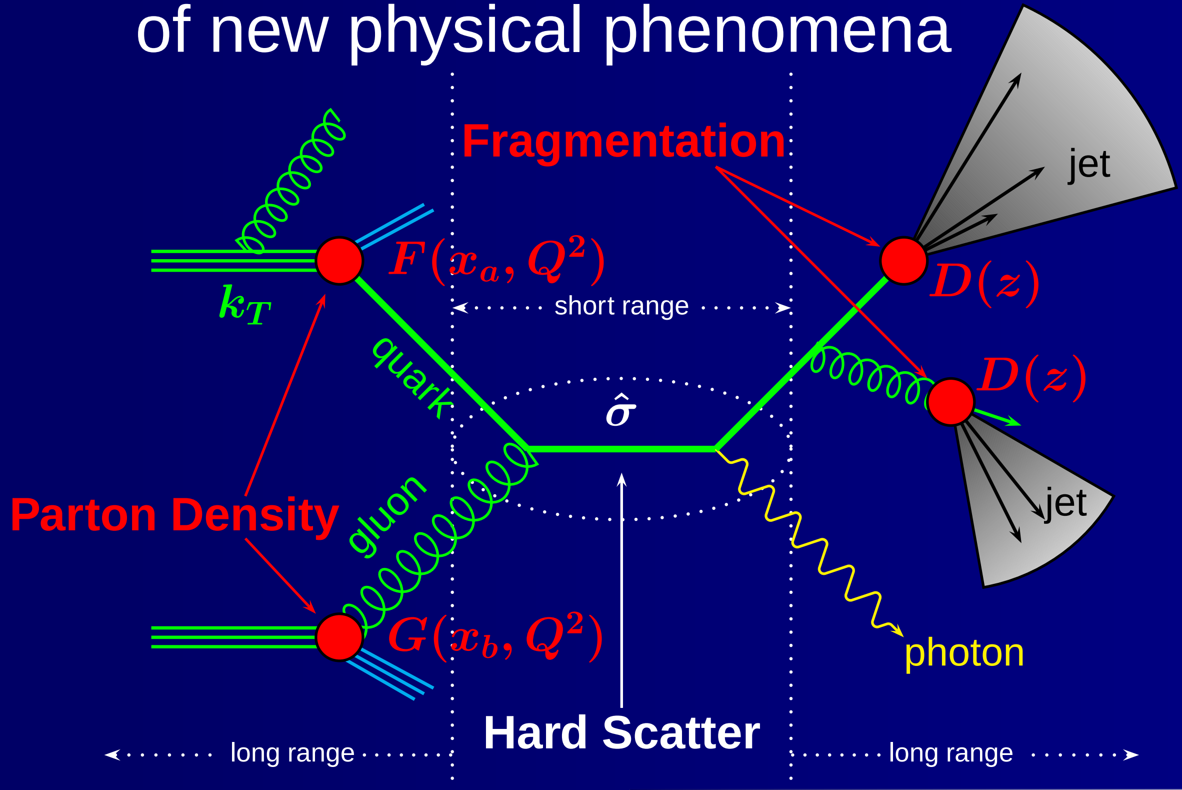
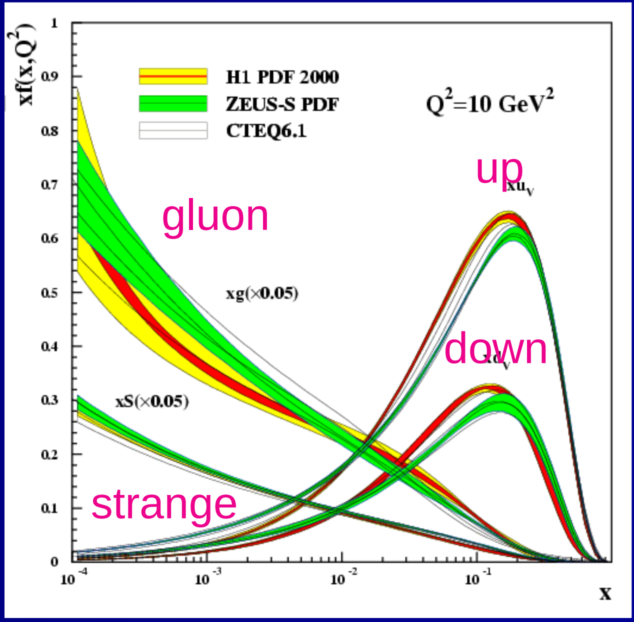
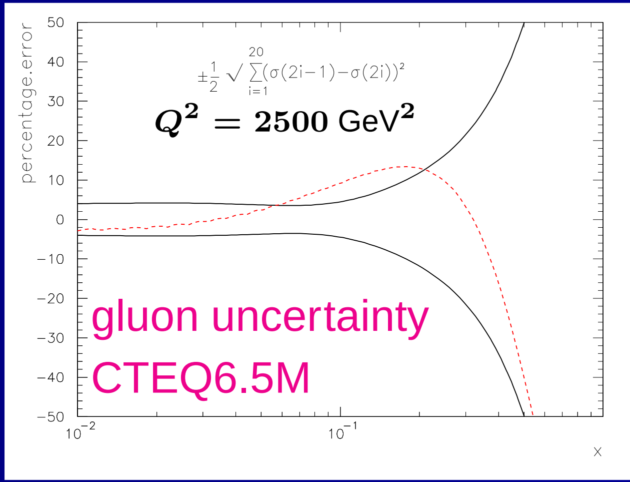
QCD Hard Scatters

Large p_T processes originate in the hard scattering of partons

- allow precision tests of pQCD
- constrain parton distribution and fragmentation functions
- sensitive to the presence of new physical phenomena



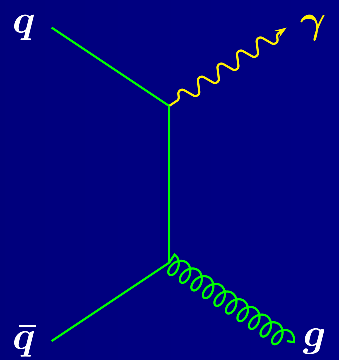




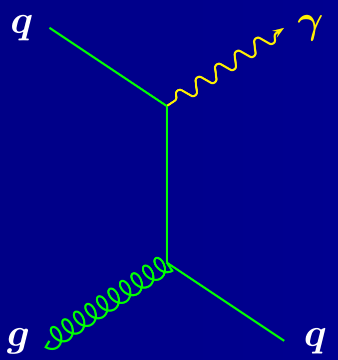
Direct Photon Production

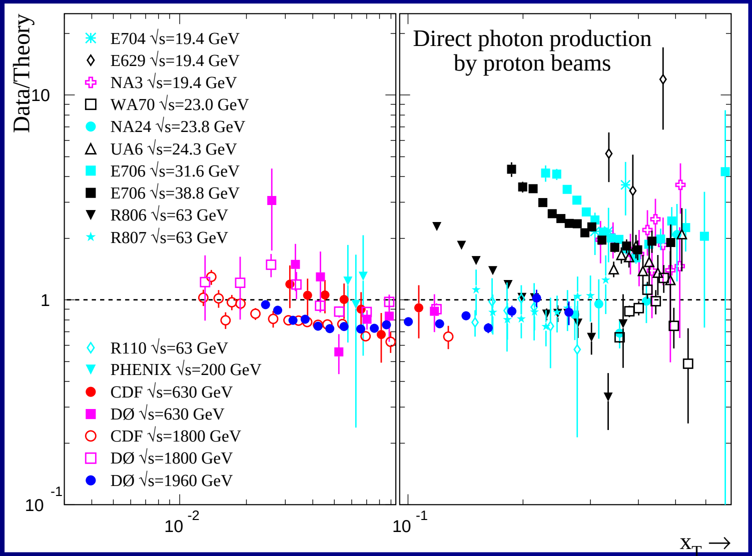
- Only two processes contribute at leading order to the direct-photon cross section
- Important higher-order diagrams include diphoton production and fragmentation diagrams ($q \longrightarrow \gamma$)
- Backgrounds are significant but measurable
- Simple diagrams suggest clean comparisons of theory to experimental data
- Originally considered the sample for extracting the high-x gluon distribution

Annihilation



Compton Scattering



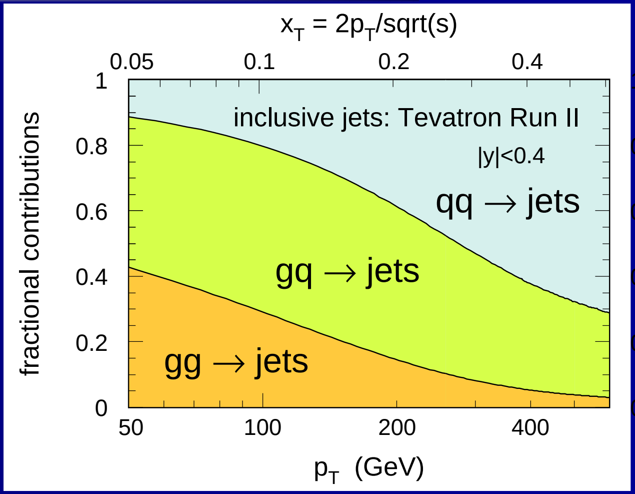


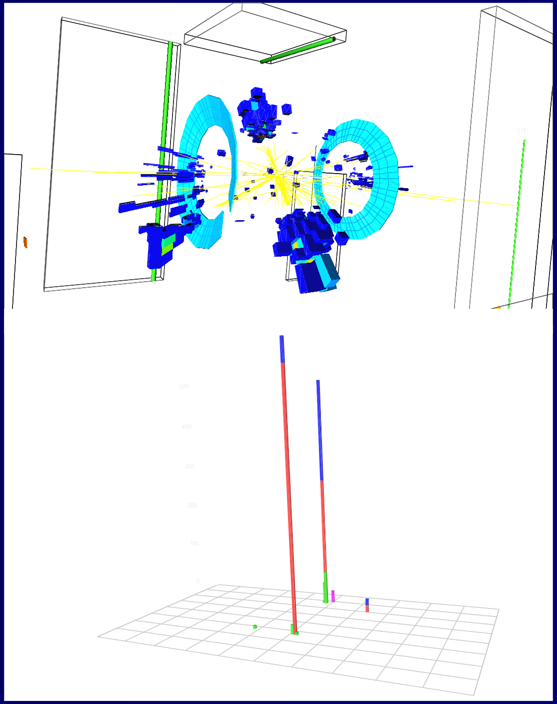
Jet Production

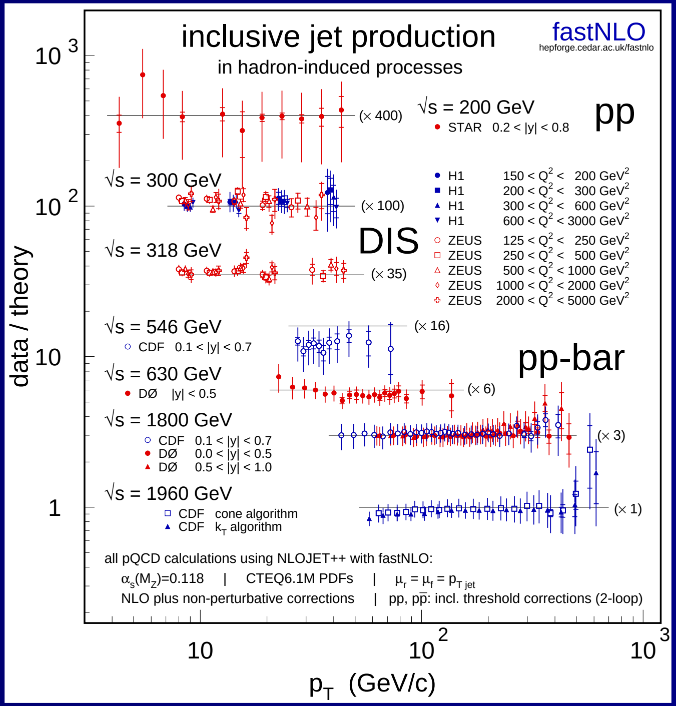
Jet production is sensitive to the gluon . . .

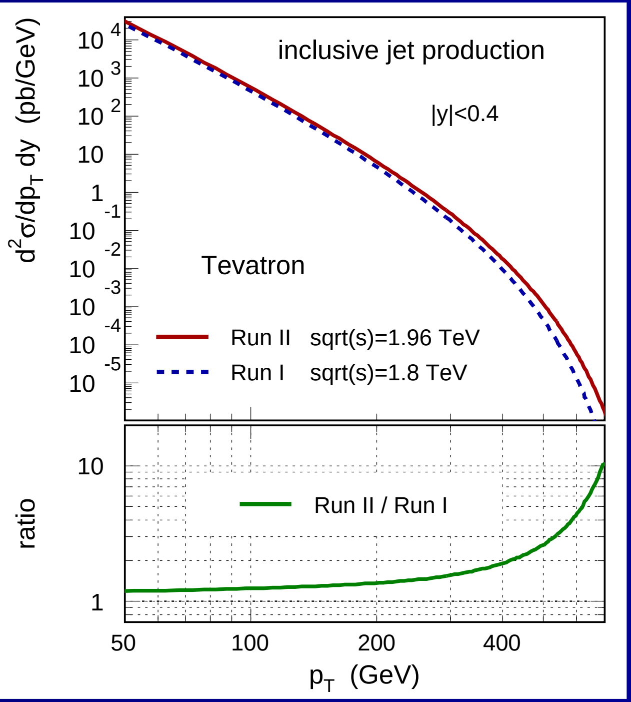
- large production cross section with small backgrounds
- pQCD theory agrees with data
- jets are defined by an algorithm

. . . and to new physical phenomena





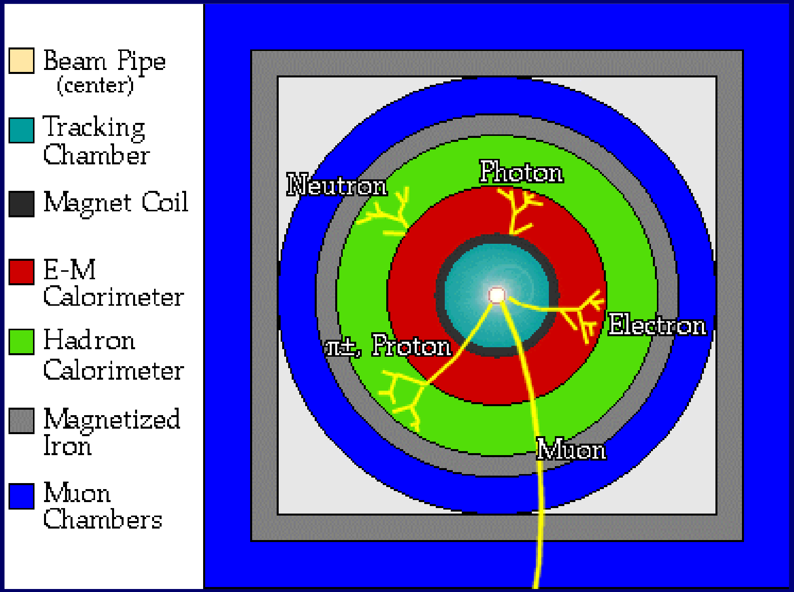


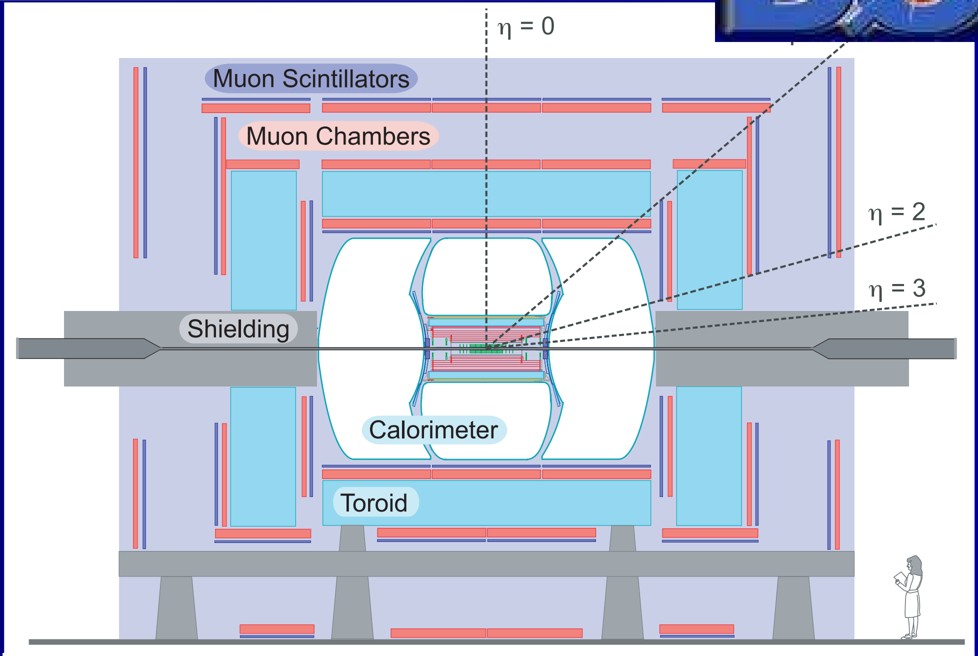


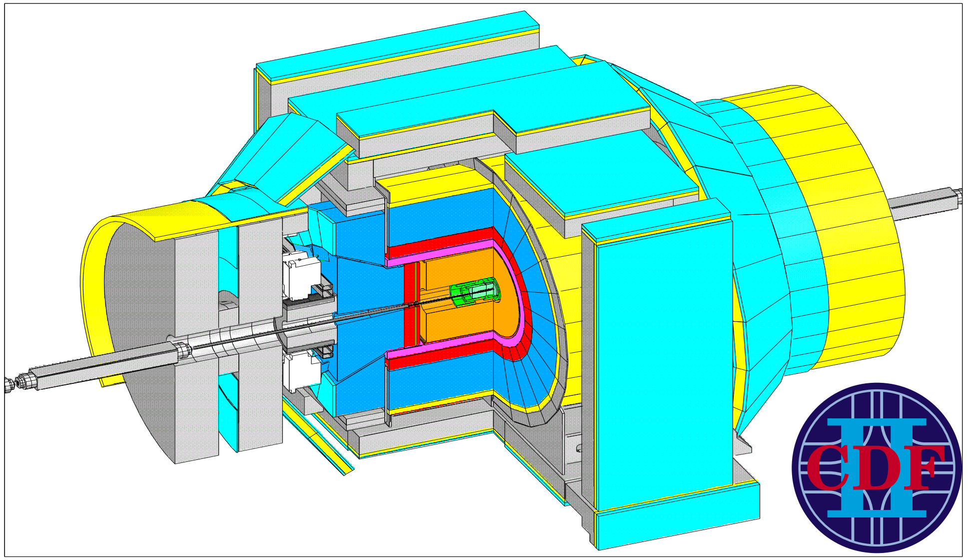
Tevatron Collider Detectors

Multi-purpose Detectors

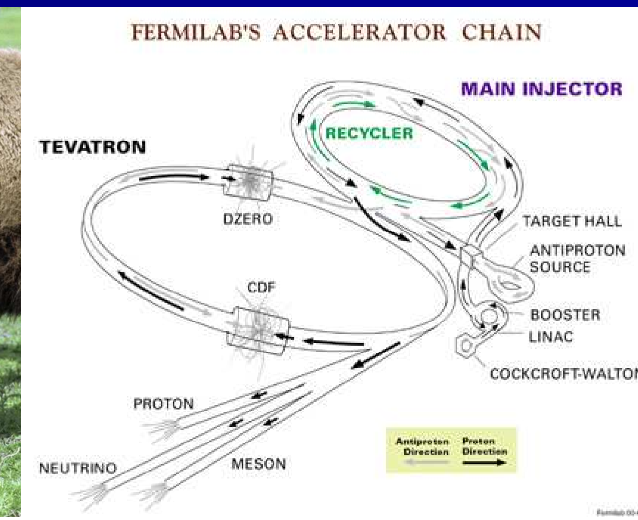
- vertexing
- precision tracking
- calorimetry
- muon system
- $\not{E}_T$ (hermetic)

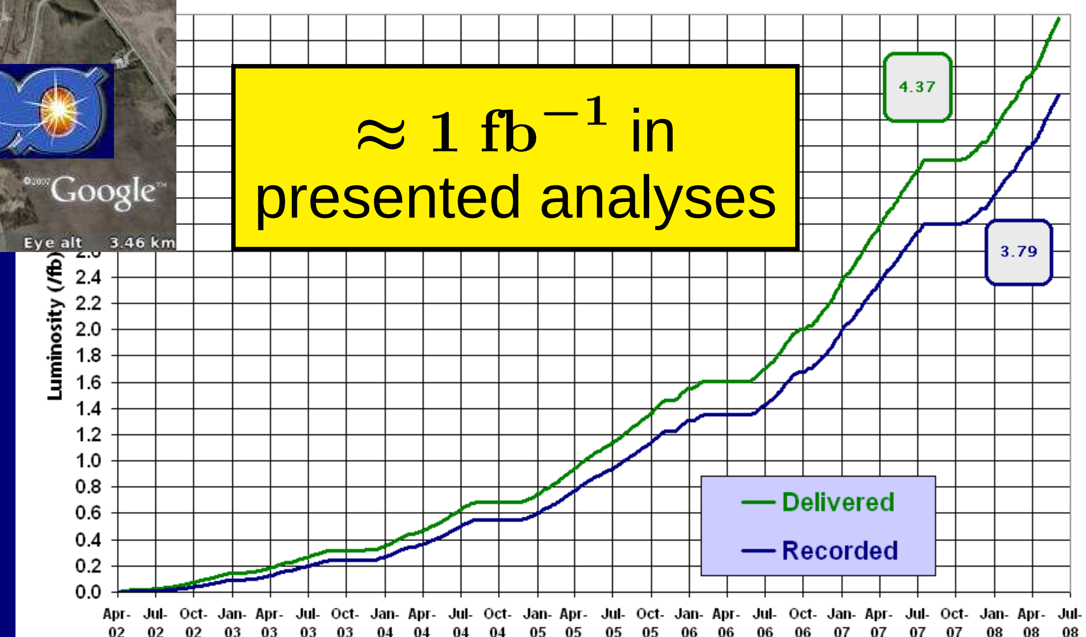






Fermilab Tevatron Collider





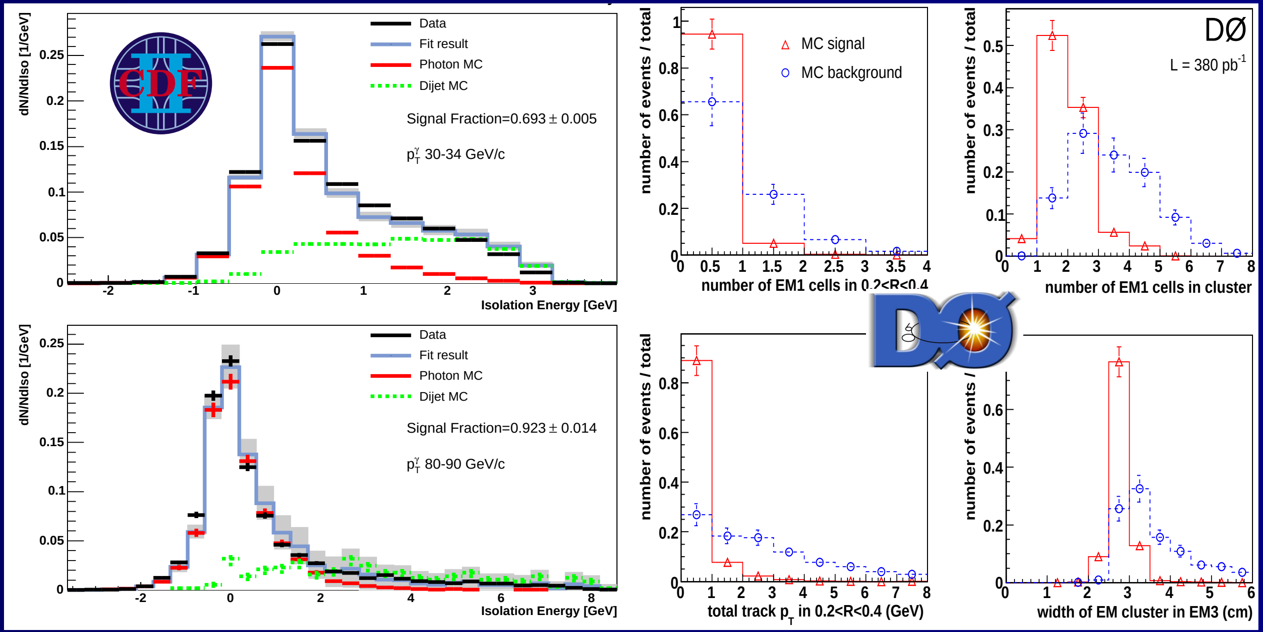
$\approx 1\ \mathrm{fb}^{-1}$ in presented analyses

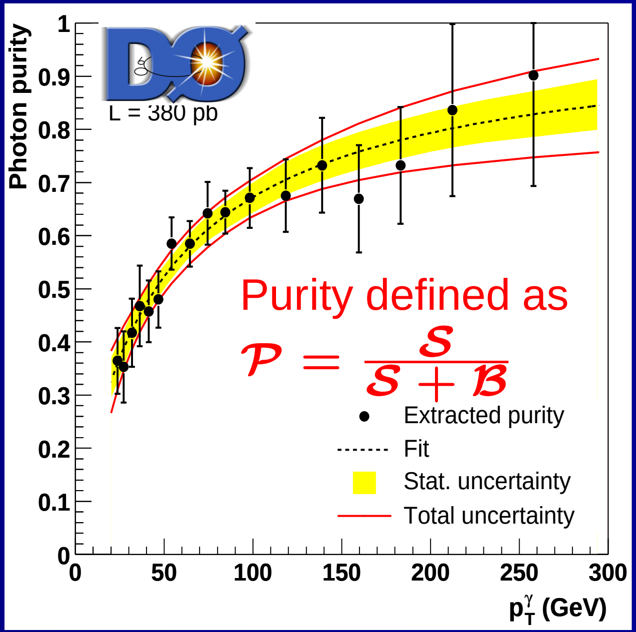
proton—anti-proton collider
978 GeV beam energy
$\Rightarrow \sqrt{s}$ =1.96 TeV
Δt=396 ns

Direct Photon Analyses

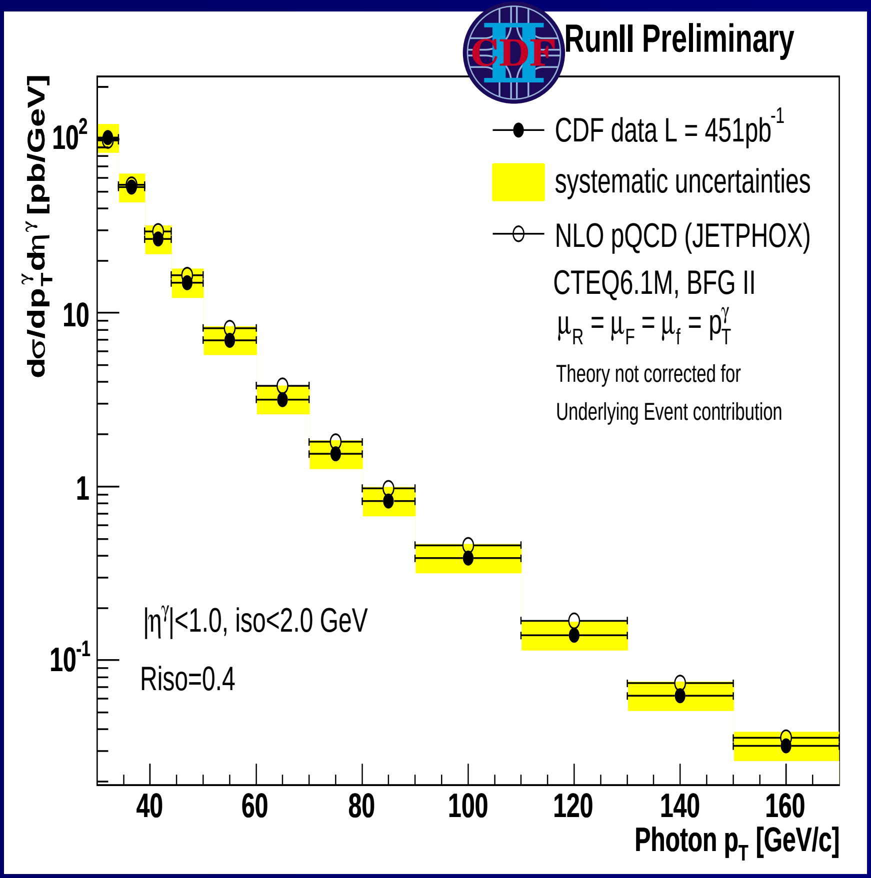
Measuring direct photon production is challenging since the signal is small compared to the potential backgrounds:

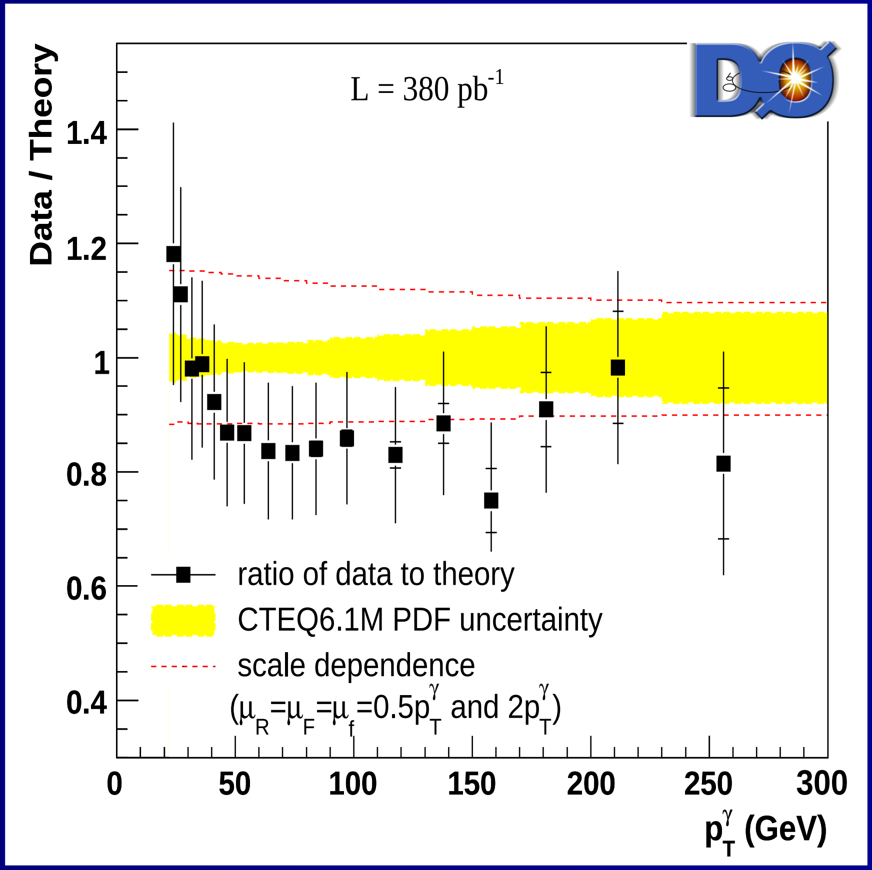
- Dominant background are photons from the electromagnetic decay of particles such as π^0 and η mesons
- Photon candidates are isolated to suppress background
- Characteristics of the reconstructed shower are used to discriminate between signal and background





Inclusive Direct Photon Production





Theory agrees with data within uncertainties but discrepancy in shape similar to other experiments (CDF Run I, UA2, E706, . . .)

Photon+Jet Production

Measure isolated photons with associated jet production

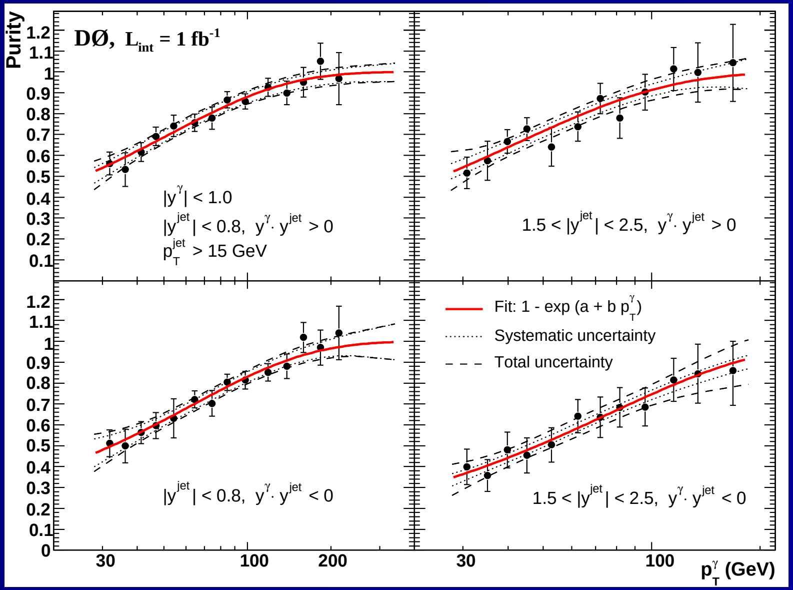
Increases sensitivity to the gluon distribution

Rely on jet direction not p_T: $\dfrac{\mathrm{d}^3\sigma}{\mathrm{d}p_T^\gamma\,\mathrm{d}y^\gamma\,\mathrm{d}y^{\mathrm{jet}}}$

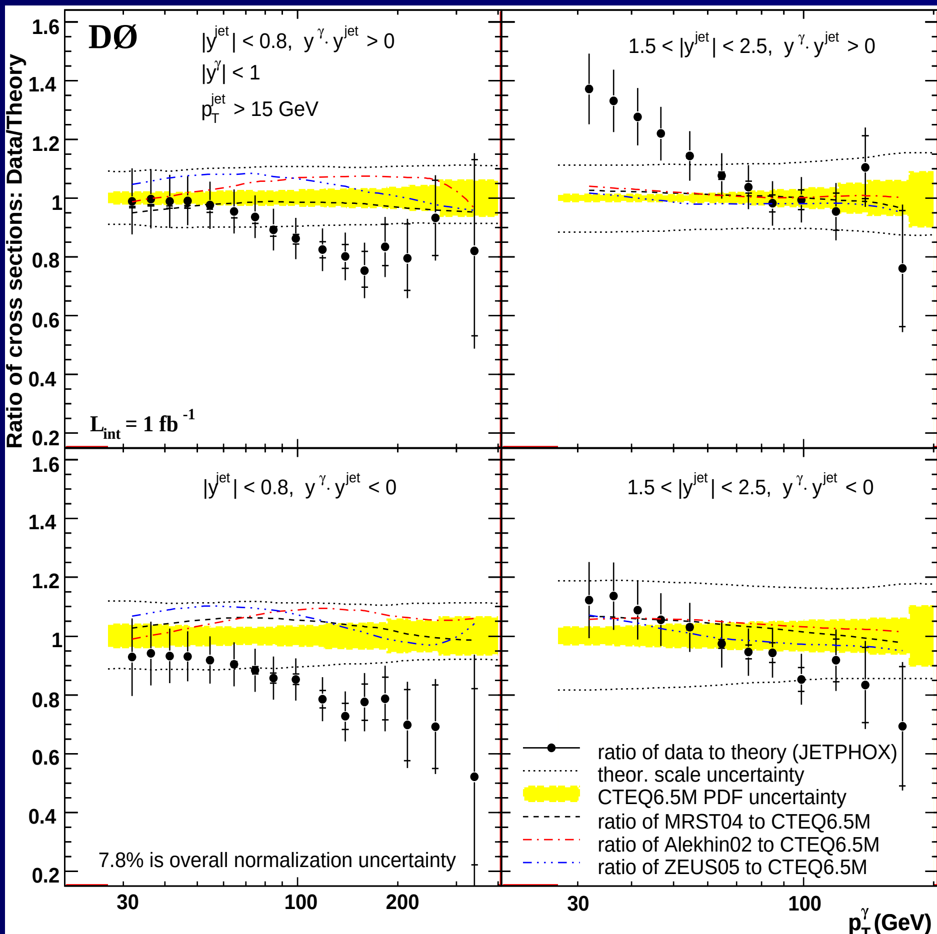
- $|y^\gamma| < 1.0$
- $p_T^{\mathrm{jet}} > 15$ GeV and $|y^{\mathrm{jet}}| < 0.8$ or $1.5 < |y^{\mathrm{jet}}| < 2.5$

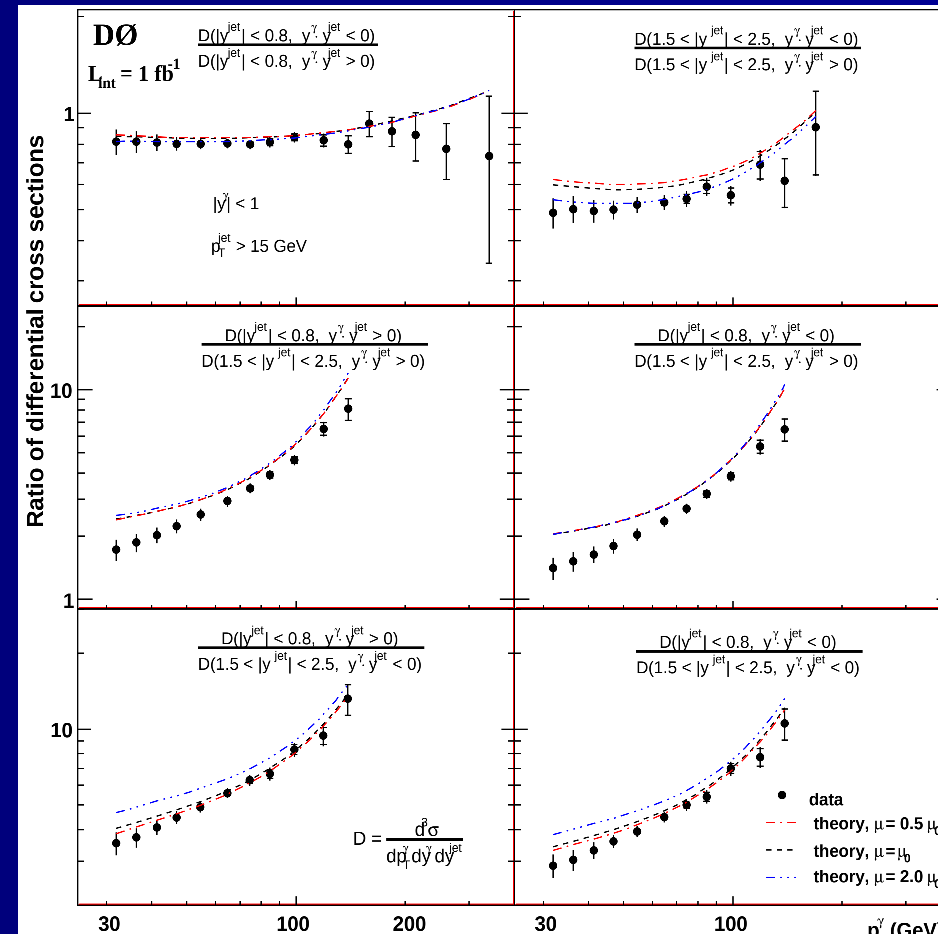
Define four regions based on y^{jet} and the sign of $y^\gamma \cdot y^{\mathrm{jet}}$:

- $|y^{\mathrm{jet}}| < 0.8,\ y^\gamma \cdot y^{\mathrm{jet}} > 0$
  $0.016 \lesssim x_1 \lesssim 0.040$ and $0.040 \lesssim x_2 \lesssim 0.100$
- $|y^{\mathrm{jet}}| < 0.8,\ y^\gamma \cdot y^{\mathrm{jet}} < 0$
  $0.029 \lesssim x_1 \lesssim 0.074$ and $0.027 \lesssim x_2 \lesssim 0.065$
- $1.5 < |y^{\mathrm{jet}}| < 2.5,\ y^\gamma \cdot y^{\mathrm{jet}} > 0$
  $0.009 \lesssim x_1 \lesssim 0.024$ and $0.110 \lesssim x_2 \lesssim 0.300$
- $1.5 < |y^{\mathrm{jet}}| < 2.5,\ y^\gamma \cdot y^{\mathrm{jet}} < 0$
  $0.097 \lesssim x_1 \lesssim 0.264$ and $0.022 \lesssim x_2 \lesssim 0.059$



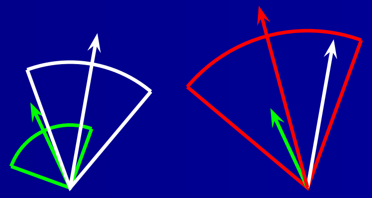
Photon+Jet Production



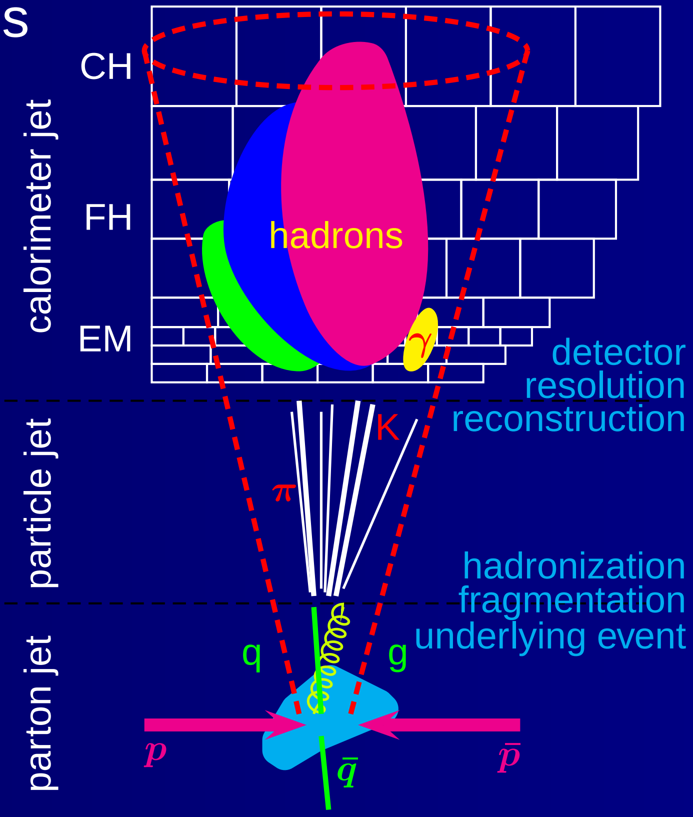


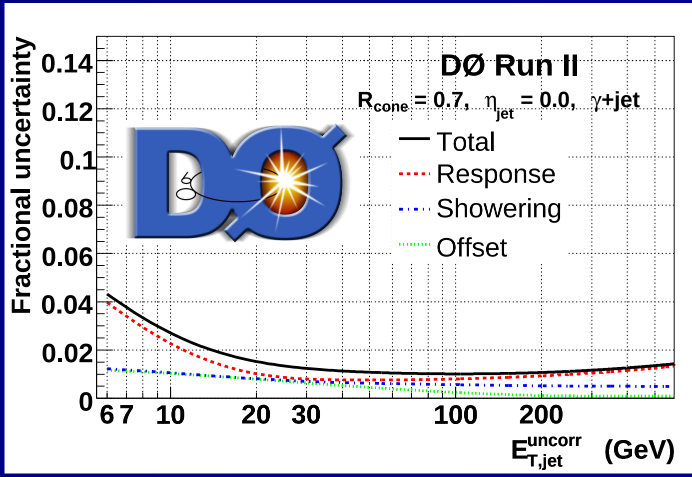
Disagrees in shape like inclusive results; also significant disagreement in ratios of one region to another

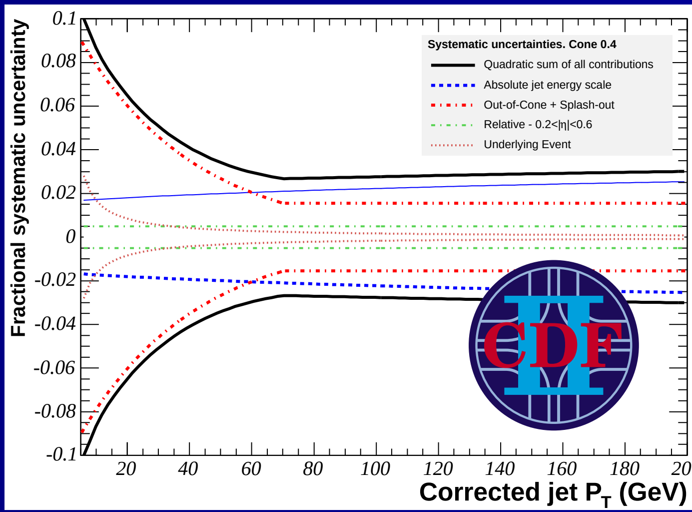
Jets



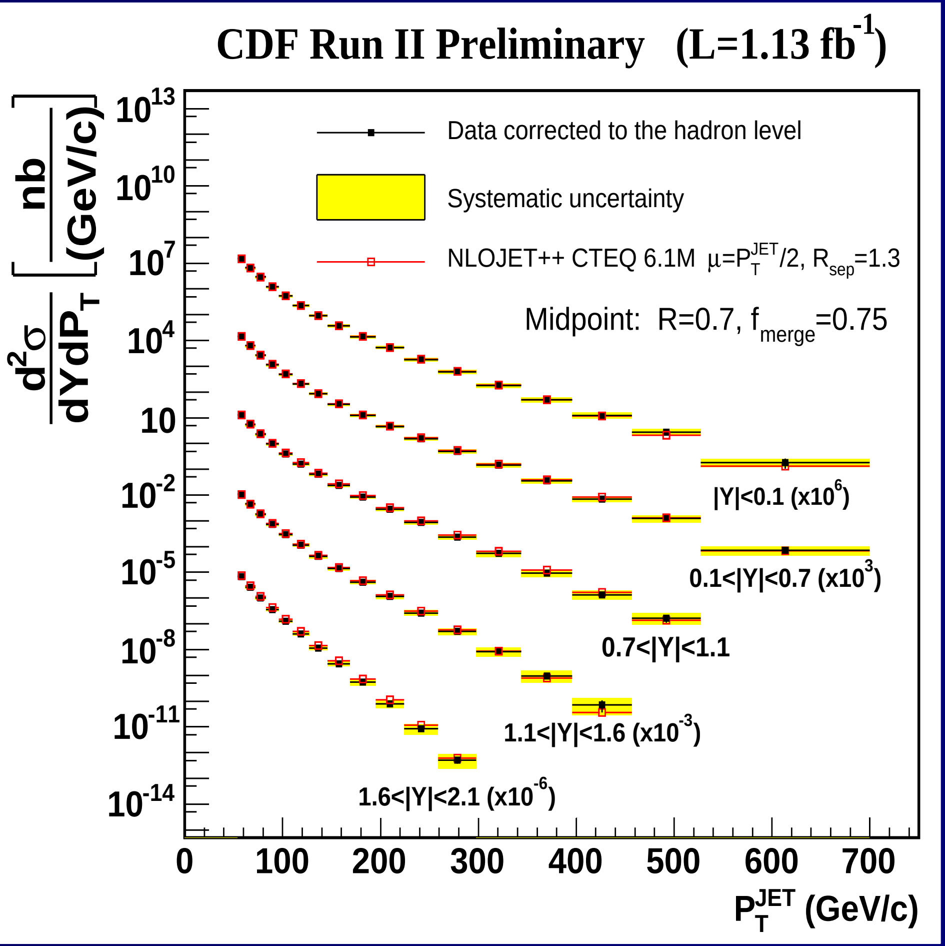
- Reconstruct jets using iterative cone algorithm with mid-points ($\mathcal{R} = 0.7$)
- Calibrate jet energies to particle level
  - zero and minimum bias events
  - single particles
  - γ+jet events
  - Z+jet events
  - dijet events
  - simulation
- Correct to parton level (CDF)
- Correlation Matrix (DØ)

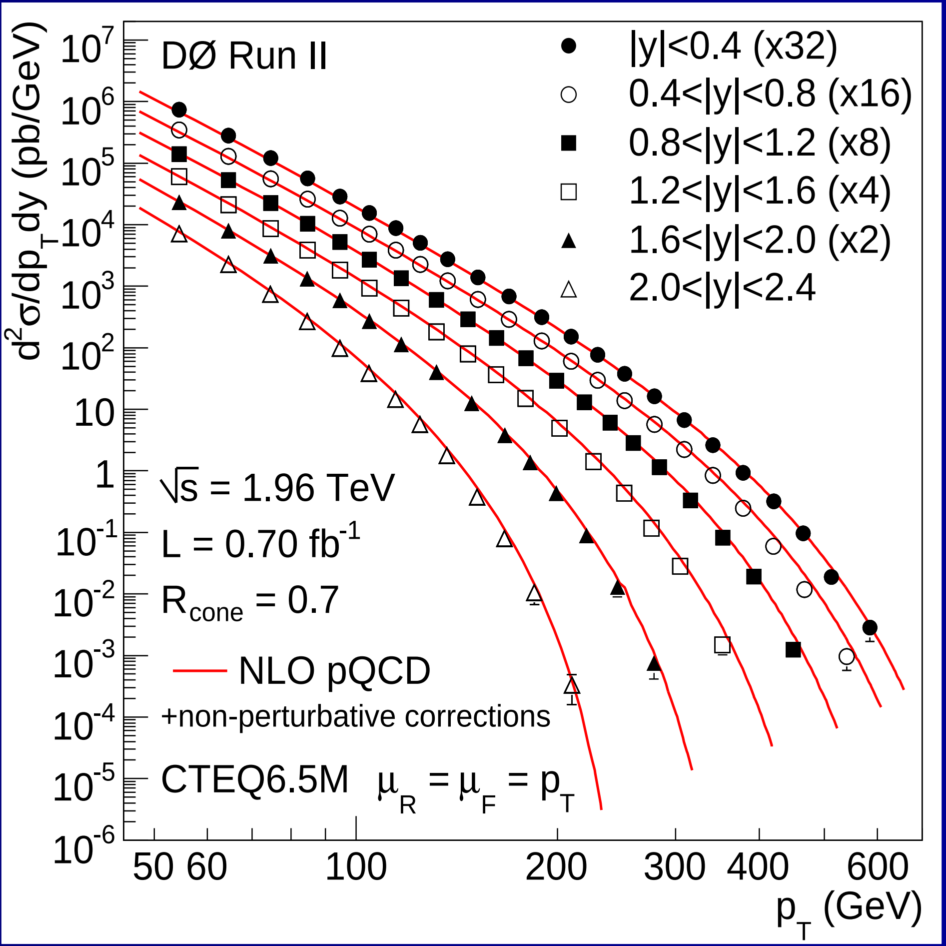






Inclusive Jet Production



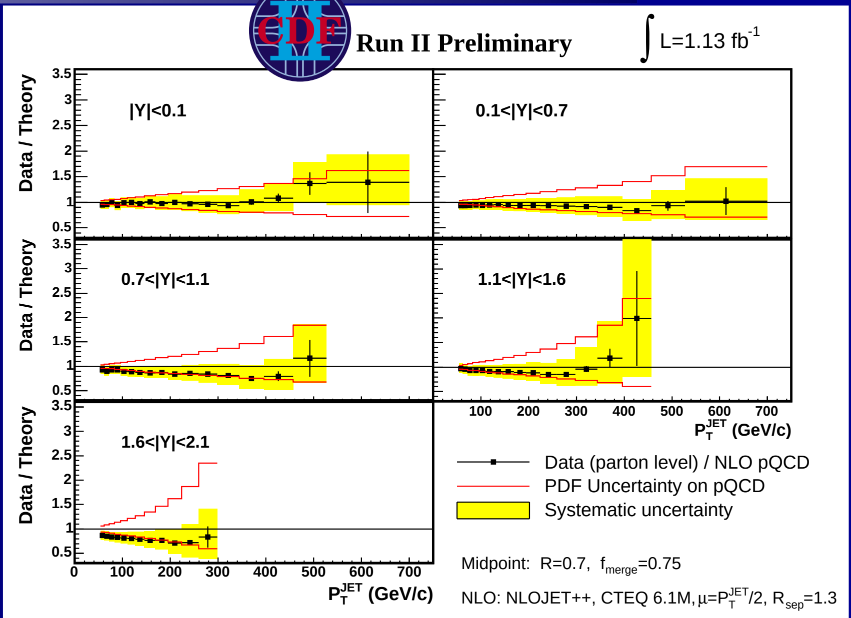


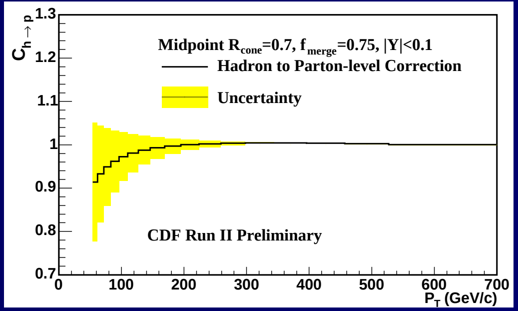
It is important to measure jet production over a wide range in rapidity to both constrain the gluon distribution and maintain sensitivity to new physical phenomena.

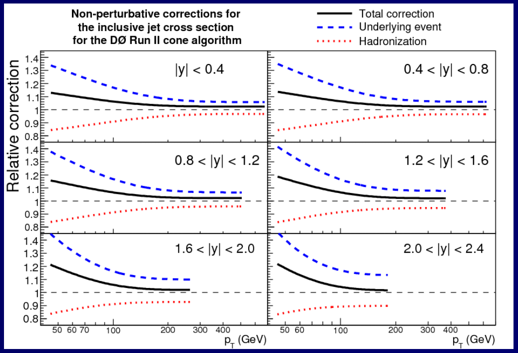
Inclusive Jet Production

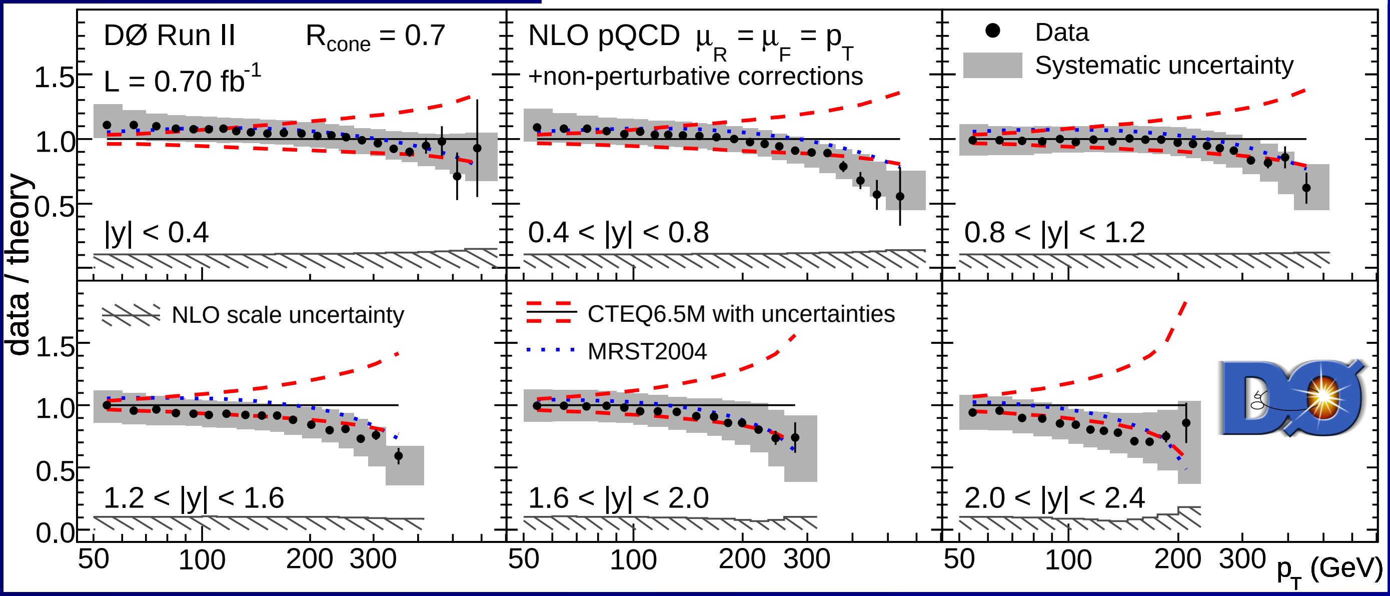
Good agreement between theory and data. Both CDF and DØ tend to lie along the lower edge of the CTEQ PDF uncertainty band.

These measurements will be important inputs in the next round of global PDF fits.

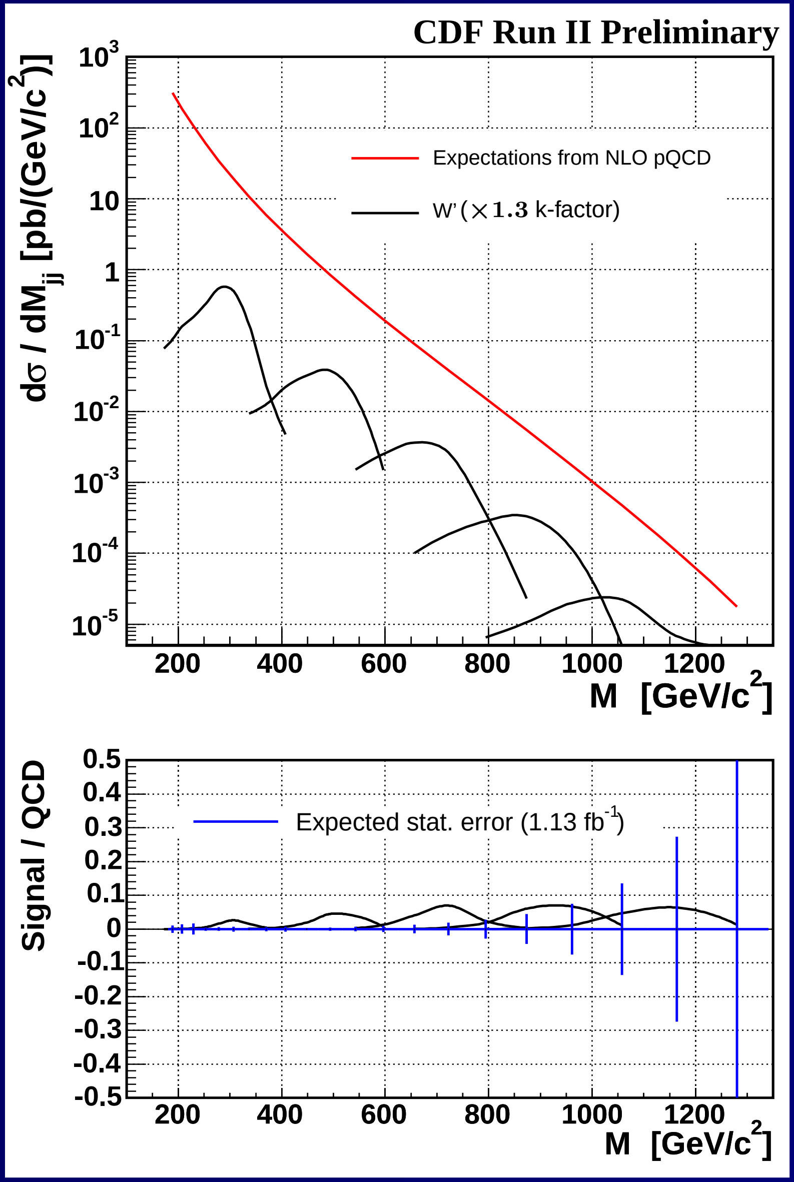






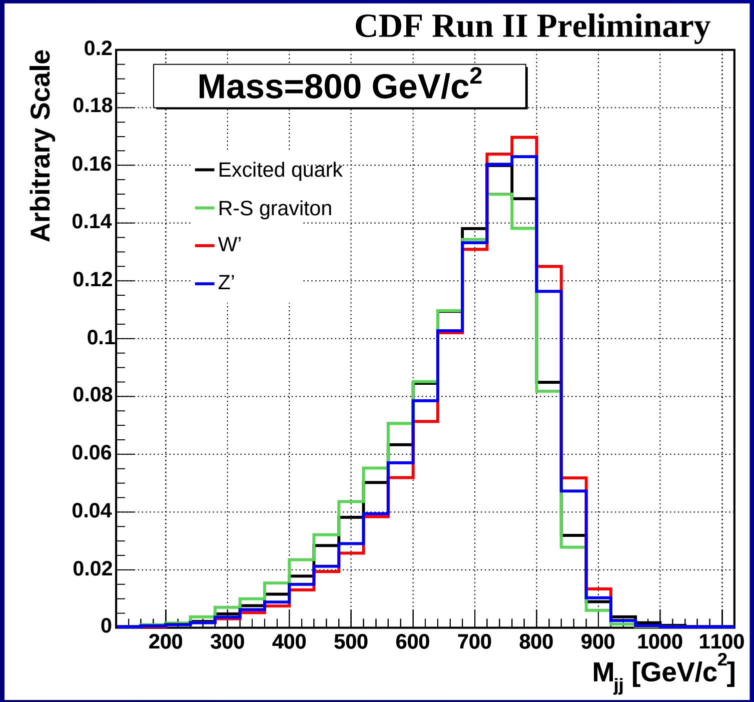


Dijet Mass Distribution

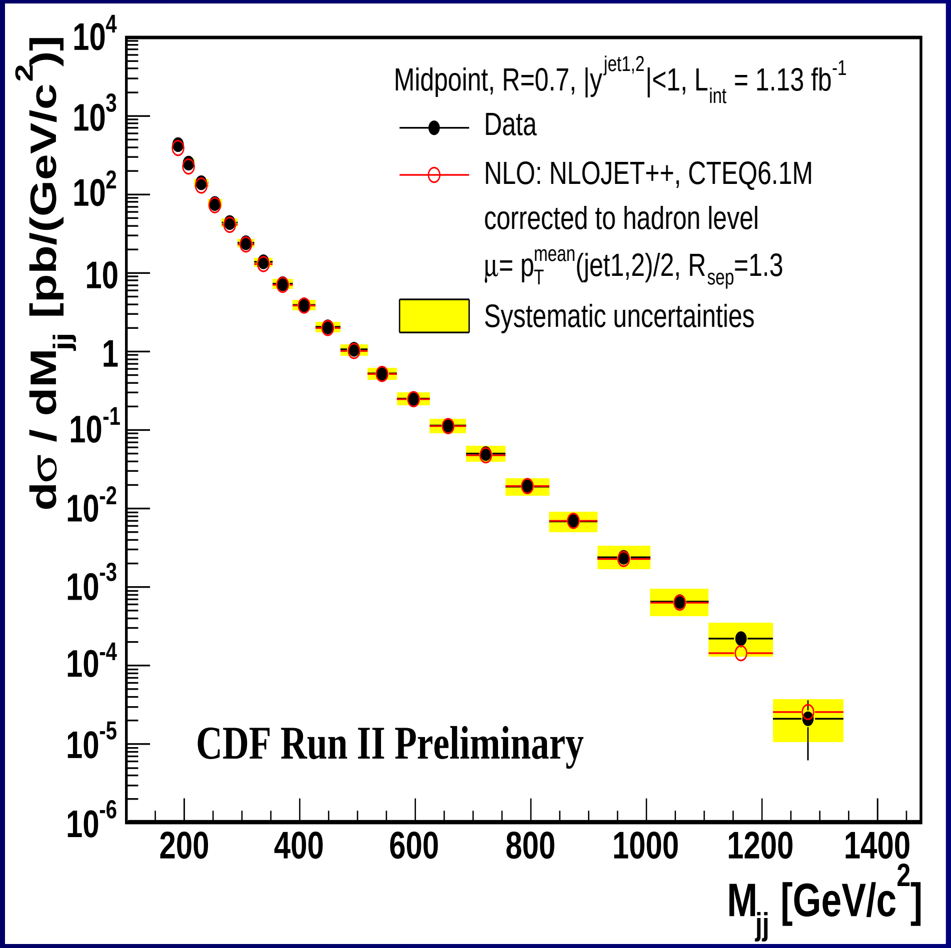


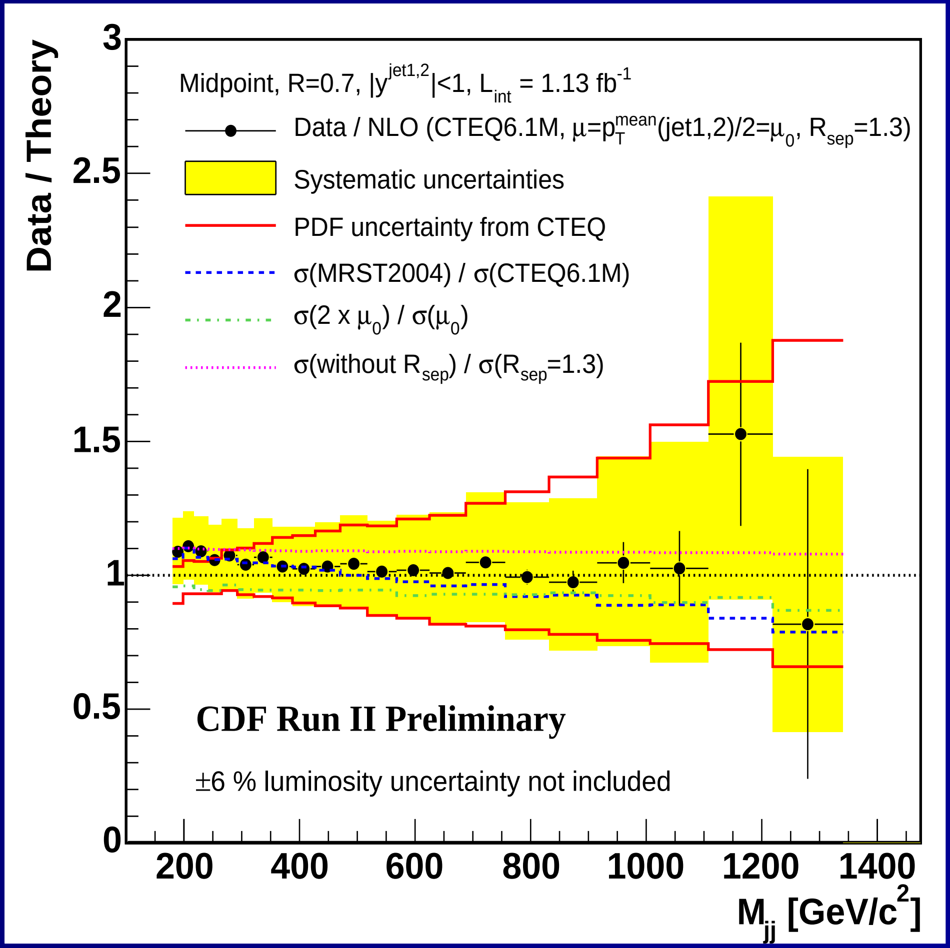
Dijet mass spectrum tests pQCD and has enhanced sensitivity to the presence of new physical phenomena:

- many models predict dijet resonances
- width dominated by detector resolution



Dijet Mass Distribution

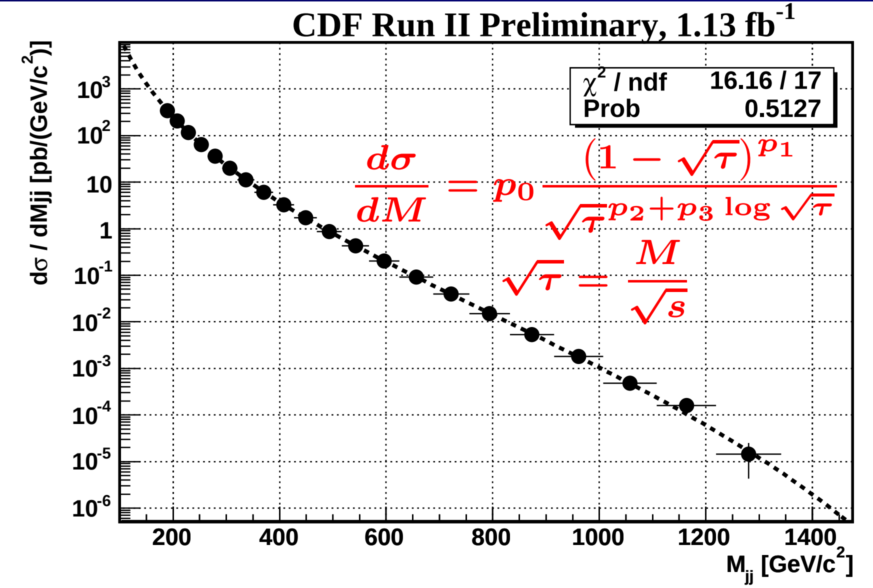




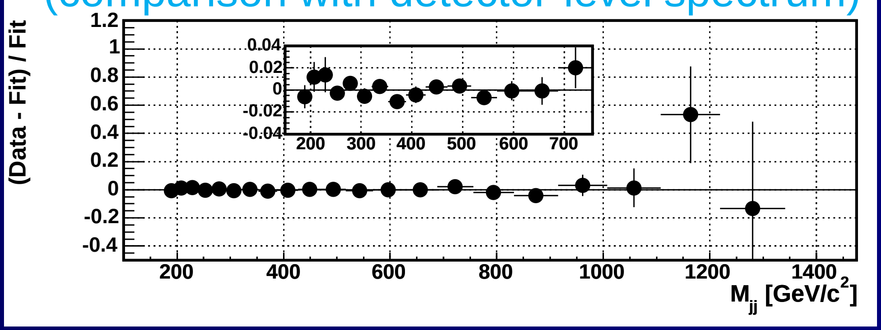
NLO pQCD agrees very well with the dijet mass distribution

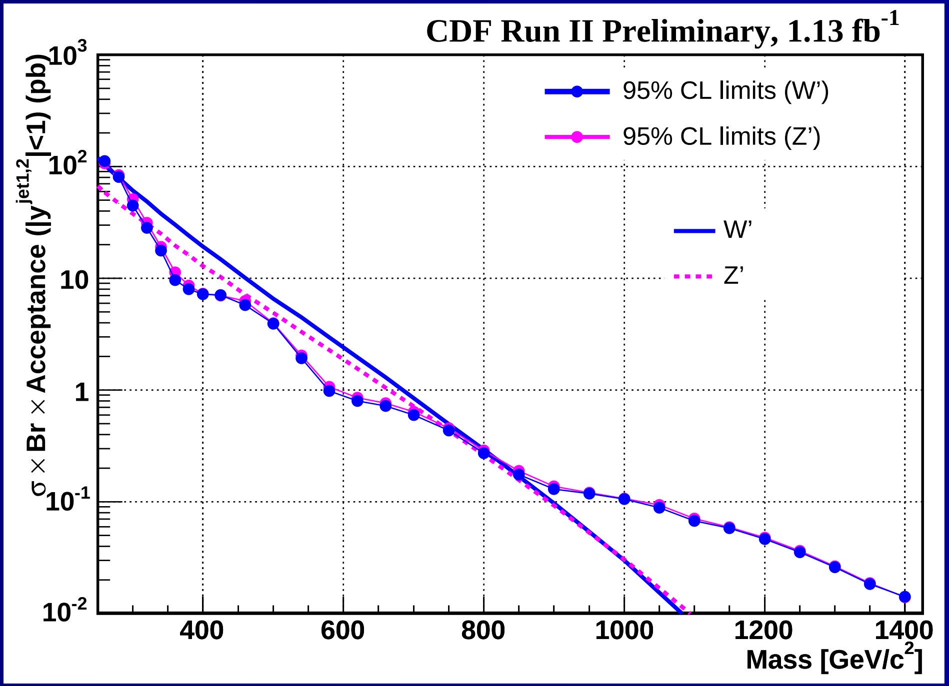
Dijet Mass Distribution

No significant indication of resonant structure in dijet mass spectrum has been observed



(comparison with detector-level spectrum)

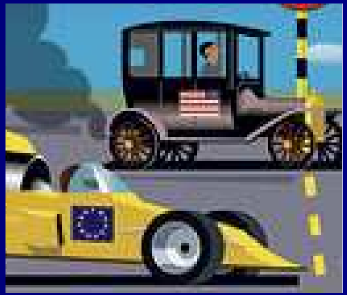


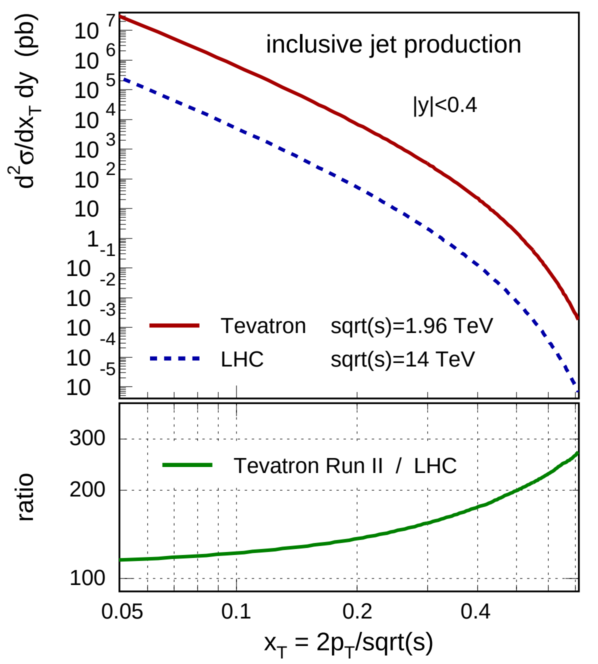


Observed Exclusion	Model
$280 - 840$ GeV	W' (SM couplings)
$320 - 740$ GeV	Z' (SM couplings)
$260 - 870$ GeV	Excited quark (SM couplings)
$260 - 1100$ GeV	Color-octet technirho
$260 - 1250$ GeV	Axigluon & flavor-universal coloron
$290 - 630$ GeV	$E6$ diquark

Conclusions

- The Tevatron program has a rich tapestry of photon and jet measurements – more than can be described in this talk.
- Direct photon results from current run of the Tevatron collider show similar discrepancies in shape as earlier measurements at the Tevatron, SppS, ISR, . . .
- Tevatron jet measurements are now being incorporated into the next generation of global PDF fits and will have a major impact on the gluon distribution.
- We have not seen signs of new physical phenomena with photons or jets.
- While the LHC has higher energy reach than the Tevatron, it will require ~ 200 fb^{-1} before the sensitivity at high-x is equivalent to the Tevatron.

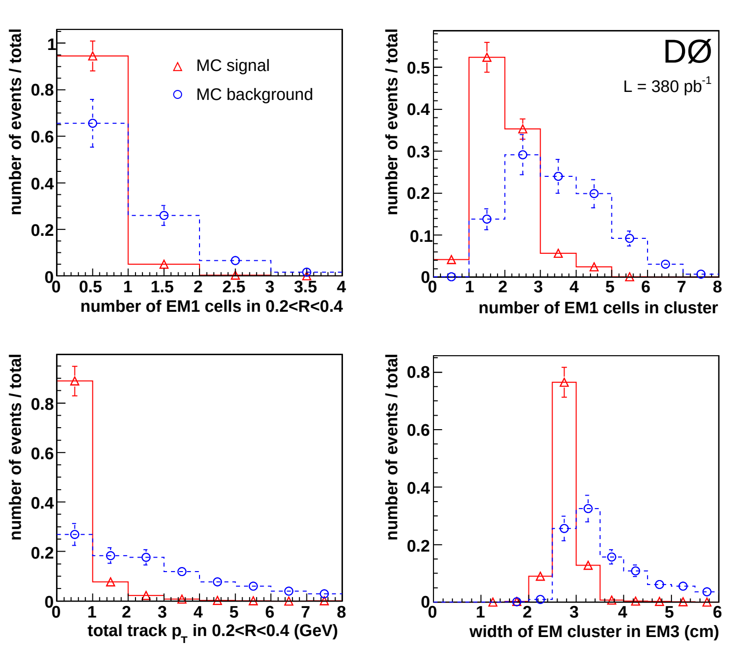


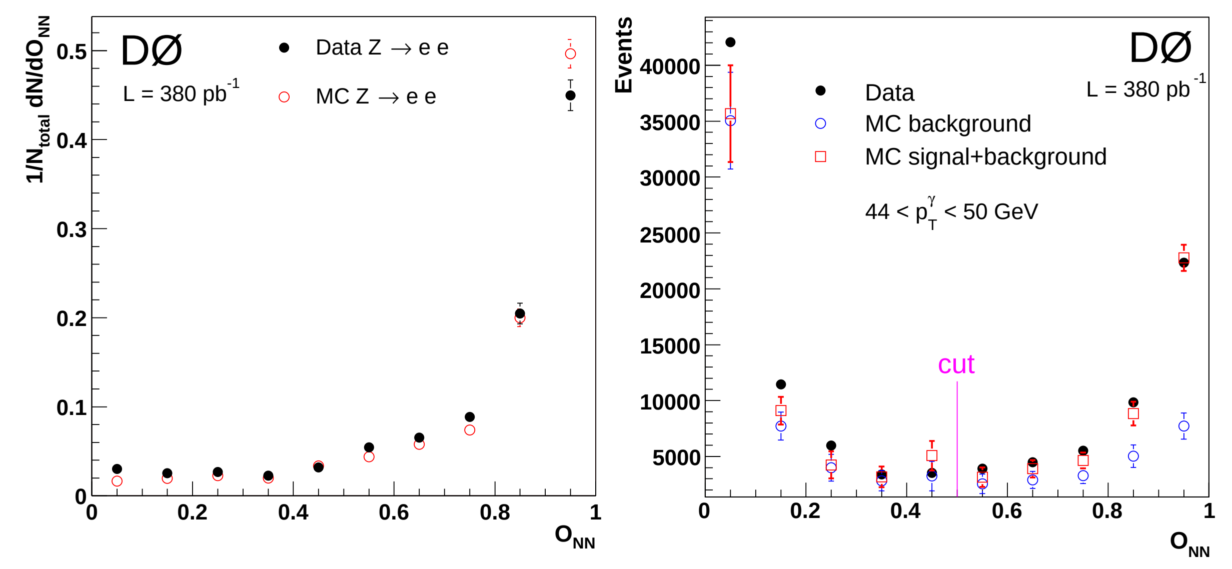


Backup Slides

Signal and Background

- Signal and background simulated with PYTHIA and processed through GEANT simulation
- Artificial neural networks were constructed to discriminate between signal and background
  different ANN constructed for inclusive photon, photon+jet, and jet energy scale analyses
- ANN validated with $Z \rightarrow e^+e^-$
- Cuts placed on ANN to improve background rejection
  $O_{\mathrm{NN}} > 0.5$ for inclusive
  $O_{\mathrm{NN}} > 0.7$ for photon+jet





Comparisons with Other Data